

AC 2008-397: ENHANCING DESIGN LEARNING BY IMPLEMENTING ELECTRONIC PORTFOLIOS

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Enhancing Design Learning by Implementing E-Portfolios

Abstract

This paper presents the findings of a pilot intervention that implemented e-portfolios to enhance design learning at The Pennsylvania State University (Penn State). It will answer the following questions: (1) What type of guidance do students need to develop meaningful content for their portfolios? and (2) How do we assess the portfolio content? The paper includes a description of the rubrics used to assess students' e-portfolio content. The Model of Domain Learning (MDL) formed the basis of the rubric development. The results revealed the importance of reflective writing in the development of ABET-aligned World Class Engineer attributes along the dimensions of the MDL, in particular the development of knowledge. The project was partially funded by the Leonhard Center for the Enhancement of Engineering Education and Social Science Research Institute at Penn State.

Introduction

Design is a key component of a majority of engineering disciplines. The importance of design in engineering education is evident in a key learning outcome criterion set by the Accreditation Board for Engineering and Technology (ABET), which states that students are expected to demonstrate “the ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability”¹. Most four year engineering programs include a cornerstone design course in the first year which introduces students to the breadth of engineering design topics. Students obtain more in-depth knowledge in their second and third year, in particular related to engineering analysis. Although analysis is a relevant part of the design process, when asked to describe their experience with engineering design, junior engineering students often refer to their cornerstone design course but not to their second and third year coursework. This means that students do not recognize their analytical training as a necessary part of their design preparation. Despite this disconnect, these students are expected to pull their analysis training together with their first year design experience to successfully complete a capstone design project in their senior year. Based on this, we assert that design learning needs to be enhanced to integrate seemingly disparate pieces of design knowledge and skills. Empirical evidence supports this assertion.²

A proven way to enhance learning is to engage students in their own learning, for example by having them document and reflect on their learning experiences. Increasingly, electronic portfolios (e-portfolios) are gaining attention as a solid assessment tool as well as a pedagogical tool. As a pedagogical tool, e-portfolios serve to communicate high expectations and support learner-centered instruction. We hypothesize that documentation of engineering design learning in an e-portfolio will enhance students' learning.

The empirical literature supports the belief that active learning supports student outcomes^{3,4}. Students who are engaged in active learning are more likely to progress through stages of

academic development⁵ and students' individual effort is the primary determinant of the impact of college³ (p. 602). Similarly, many educational psychologists argue that self-regulated learning is a requirement for high quality learning. A student who can self-regulate is able to meta-cognitively control her own learning⁶, employ effective strategies⁷, and motivate herself appropriately⁸. These views are also consistent with Francis, Mulder, and Stark's argument (1995) that the intentional learner is the best learner. The intentional learner asks independent questions about the material to be learned (questioning), develops an understanding of what is learned (organizing), integrates what is learned into a broader pattern of understanding (connecting), and understands her learning needs and strategies (reflecting)⁹ (pp. 13-15).

In a culture of student-centered, active learning, students are expected to take responsibility for their learning. As a result of this expectation during the college years, students are increasingly given opportunities to practice active learning. Because practice is necessary for the internalization of complex learning processes⁸, we believe that a student-centered culture contributes significantly to the development of professional engineers who are life-long learners¹⁰ (p. 208).

E-portfolio development is a pedagogical tool that is promising as a means for promoting active learning. Portfolios are based on constructivist theory, which supports the principles of student-centered instruction and encourages instructional practice that fosters active learner involvement. Although portfolios have only recently become popular across academic disciplines, the fields of Arts and Education have used this practice to showcase students' work for some time. Consistent with the recent interest in the use of portfolios, in ABET criterion 3, portfolios are mentioned as one way to document and assess student outcomes¹.

A portfolio is a collection of work ("artifacts") that demonstrates certain competencies from which the student has selected a subset to demonstrate growth over time. The portfolio contains a reflection on each artifact as well as an overall reflection on the content of the portfolio (see for example¹¹). One of the most important advantages of portfolios is their potential to engage students in intentional learning, resulting in an increased ability in life-long learning^{12, 13, 14, 15, 16, 17}. Portfolios are expected to have a positive effect on attitudinal, motivational, affective, and professional outcomes¹². These may include increased self-confidence, increased awareness of professional identity, more positive attitudes toward profession, improved career-decision self-efficacy, and increased ability to build a network of professionals. DiBiase¹⁸ described many other potential benefits of e-portfolios including an increased learning effectiveness for students, the opportunity for faculty to leverage student motivation and align objectives and evaluation strategies, and the opportunity for a university to respond to calls for greater accountability and outcomes-based accreditation. While students gather evidence of their own learning, ideally they will go through the steps described earlier⁹, starting with questioning and organizing, and ending with adapting.

E-portfolio construction contributes to students' development and internalization of active learning processes. Because these processes are needed to support life-long learning, portfolios have the potential to contribute to professional development well beyond the college years. With the current generation of students being greatly influenced by information technology¹⁹, reflected in for example an overwhelming interest in Facebook²⁰, and that e-portfolios are much

easier to share among various constituents than paper portfolios, e-portfolios offer students a great learning opportunity that can guide them in becoming engaged learners. In this study we wanted to leverage these advantages and use e-portfolios as a formative assessment technique that will simultaneously promote student learning and allow for the on-going assessment of design learning.

ABET expects institutions to have detailed student learning objectives in place that are consistent with the institutions' mission and with ABET's criteria²¹. With the assistance of an external board made up of a broad cross section of industry leaders, Penn State University's College of Engineering has developed a set of attributes that address the inclusion of the new demands for professional skills²²; our College's strategic plan includes the mission to prepare students to become World Class Engineers (WCE) who are Aware of the World, Solidly Grounded in Fundamentals of their chosen engineering discipline, Technically Broad with respect to their knowledge in various engineering disciplines, Innovative, Effective in Teams, and Successful as Leaders.

The research team evaluated e-portfolios for evidence that students are developing design expertise related to the domains of three of the WCE attributes, namely Solidly Grounded, Technically Broad, and Effective in Teams. We chose these three WCE attributes, because they were most applicable to the first year design course in which e-portfolios would be used—we could not assess all six attributes because of time constraints. Three criteria were necessary to assess the e-portfolio content. First, in order for the assessment tools to be sensitive to the development of professional engineers, these tools must evaluate the attributes that comprise the World Class Engineer. Second, the tools must be grounded in a recognized model of development. Third, because the e-portfolios will be used over time, the assessment techniques must be able to detect change. To meet these three criteria, we developed an assessment technique that synthesized a model of domain learning with the attributes of the World Class Engineer.

Alexander's Model of Domain Learning (MDL)⁵ was used as the theoretical framework that structured and guided evaluation of these three attributes. In the MDL, students develop through the three stages of acclimation, competency, and, finally, proficiency. Within each stage, the four dimensions of domain and topic knowledge, strategies, and interest interact to influence learning, and each stage is marked by a developmental shift along these dimensions. Over time, for example, reliance on domain-general strategies gives way to more powerful domain-specific strategies; interest shifts from situational to topic; and powerful, principle-driven domain knowledge supports learning and problem solving. The MDL lends itself to longitudinal measurement because it was developed to describe change over time. In this theory, evidence of development is obtained when students show shifts along the four dimensions toward expertise.

We developed assessment rubrics that are grounded in both the World Class Engineer and the MDL by setting these frameworks against one another in a single matrix. Specifically, for each of the dimensions of the MDL (e.g., domain knowledge, strategies, etc.) we developed a matrix with progressive rows that correspond to each of the expert levels dimension of the MDL. This matrix can be used to assess each of the World Class Engineer attributes. The rubrics are explained in more detail in the section "Rubrics for Assessment of E-Portfolio Content" below.

Each portfolio entry was read to locate evidence related to one of the three World Class Engineer attributes. This evidence was examined to assess the learners' developmental stage based on the rubrics described above. Specifically, we looked at each relevant segment to locate evidence of students' strategic processes, interest, and domain and topic knowledge. For each of these dimensions, we evaluated this evidence according to Alexander's description of development within each stage. The label for the identified stage was entered into the cell that corresponds to both the dimension and the attribute. Thus, for example, a student who showed emerging domain-specific strategies for learning about teamwork would be identified as falling within the competency stage for the strategies used to become Effective in Teams. Patterns of change over time should reveal the emerging expertise of participating students.

The overall goal of the project is to gain an understanding of design learning to enable enhancement. This paper reports on findings of the first phase of the project. It will answer the following questions: (1) What type of guidance do students need to develop meaningful content for their portfolios? and (2) How do we assess the portfolio content?

Method

Participants

Students from two sections of a first-year engineering design course in the spring 2007 semester were asked to develop an e-portfolio in which they were to demonstrate their learning related to becoming a World Class Engineer; 47 out of 64 students completed this assignment.

The E-Portfolio Template

We asked the students to demonstrate their design learning related to the three WCE attributes described above. Each student at our university has personal space on a web server, which they can use for web pages and e-portfolios. We asked students to copy an html template of an e-portfolio to their web space and edit it. The template included the matrix displayed in Figure 1 below. Students learned about the WCE attributes in two ways. Underneath each attribute was a hyperlink to a webpage that described the attributes. Also, the principal investigator of the project and a senior undergraduate student visited the two sections of the design course at the beginning of the semester to explain the WCE attributes.

Because we did not have experience with the level of quality of the evidence that students would provide without specific guidelines, we left the e-portfolio assignment fairly open in this pilot. We asked students to provide at least one piece of evidence in each row of the template. They did not have to limit their evidence to just the design course. Students were allowed to upload anything they thought would demonstrate their learning, including papers written for a class, lab reports, and paragraphs written specifically for the e-portfolio.


World Class Engineer Attributes	Design Course	Other Classes	Extra-curricular Activities
Solidly Grounded			
Technically Broad	 This document demonstrates how I am aware that real-life problems and their solutions are almost always multidisciplinary. Click here for instructions on how to replace this document with your own in MS FrontPage.		
Effective in Teams			

Figure 1: WCE Evidence Matrix included in E-Portfolio Html Template.

In one of the two sections of the design course we also asked students to write reflectively about each of their pieces of evidence, and an overall reflection about their development toward becoming a world class engineer. The html-template for this design course section looked similar to the one displayed in Figure 1 except that underneath each attribute was an extra row where students could enter reflections and an extra column to the right for an overall reflection.

The template included a link to “Tips for Self-Evaluation”, i.e. a webpage with guidelines for content development, see Figure 2. Note that the information about the reflective summary was only presented to the engineering course section that was invited to write reflectively about their learning.

Criteria Area	Ratings		
	Beginning	On Target	Exceeds Expectations
Artifacts Matrix	Incomplete matrix that does not contain artifacts that demonstrate achievement of each of the World Class Engineer outcomes (at least one artifact in each row).	Matrix that includes at least one artifact in each row that demonstrates achievement in World Class Engineer outcomes.	Complete matrix that includes artifacts that demonstrate achievement in all areas of World Class Engineer outcomes.
Follows Conventions	Submissions do not conform to the conventions of English. There are mistakes in spelling, grammar, punctuation and word usage.	Submissions conform to the conventions of English with only minor mistakes in spelling, grammar, punctuation and word usage.	Submissions conform to the conventions of English with only minor mistakes in spelling, grammar, punctuation and word usage.
Reflective Summary	Reflective narrative is essentially a factual descriptive account that answers the question, "What happened?"	An account of what happened that includes an analysis of this experience and answers the questions, "What happened? and What might this experience mean to me?"	An account of what happened that, when possible, interprets an understanding of this experience and answers the questions, "What happened? What might this experience mean? and What implications might there be for my future practice?"

Figure 2: Guidelines for E-Portfolio Development

Rubrics for Assessment of E-Portfolio Content

As described in the introduction, the Model of Domain Learning formed the starting point for the development of assessment rubrics. Evidence displayed in an e-portfolio for each WCE attribute was evaluated on the following three components: knowledge, strategies, interests⁵. Points were awarded depending on whether the evidence meets the requirements of a certain level (A = acclimation, P = proficiency, C = competence). See Table 1 below for the rubrics.

Knowledge:		
Level	Pts. Awarded	Description
A	0	Student does not have an understanding of the characteristic, e.g., does not mention any of the attributes related to the characteristic.
A	1	Provides a good understanding of the characteristic or provides evidence/artifact(s) that suggest a good understanding of the characteristic.
A	2	Provides evidence/artifact(s) and a good understanding of the characteristic but does not connect the two together.
P	3	Articulates the understanding of the characteristic with the provided evidence/artifact(s). Student provides an explanation of how the evidence/artifact(s) demonstrates their mastery of the characteristic. (Note: this can be done in a finer detail, on how well the explanation aligns with the evidence/artifacts).

C	4	Shows the same characteristics as the previous level. Students also articulate their strengths and weaknesses in the characteristic and the implications to them as engineering students. For example, what specific courses will they take to increase knowledge, clubs joined, work experience.
Strategies:		
Level	Pts. Awarded	Description
A	0	Student does not mention strategies on learning/ obtaining the characteristic.
A	1	Student mentions strategies on learning/ obtaining the characteristic
P	2	Student mentions and explains how the strategies allowed them to accomplish or hinder their ability to learn/ obtain characteristic.
P	3	Same as the level above and student explains how his/her strategies can be improved or provides alternative strategy (-ies) to learning/ obtaining characteristic.
C	4	Same as the level above, but student explains how the new/modified strategy (-ies) may improve the mastery of the characteristic in the future.
Interest:		
Level	Pts. Awarded	Description
A	0	Student does not appear to be interested in the characteristic at a personal level (e.g., sees no relevance of material learned in the classroom to his/her future as an engineer).
P	2	Student appears causally interested in the material and begins to see some minor connections to the characteristic.
C	4	Student understands the relevance and appears to have shown interest in learning the characteristic at a personal level. For example, I know the importance of learning the laws of thermodynamics as a future engineer in HVAC systems.

Table 1: Rubrics for assessment of MDL dimensions “Knowledge”, “Strategies”, and “Interest”

Results

Each student received 27 scores for the e-portfolio content: knowledge, strategies, and interest were evaluated for each of the three WCE attributes and this was done separately for evidence from the design class, from other classes, and from activities outside of class. Since the assignment was to provide at least one piece of evidence for each of the WCE attributes, we then took the maximum value for knowledge, strategies, and interest for each of the three WCE attributes. This resulted in nine scores for each student.

An exploratory multivariate analysis of variance (MANOVA) with the nine maximum scores as the dependent variables and the course section as the independent variable showed that there was no overall difference in scores between the section that was asked to write reflectively as well as provide evidence and the section that was only asked to provide evidence ($F(9, 37) = 1.52, p = .18$). However, Table 2 shows that all means are actually higher for the section with the

reflective writing assignment than the section without the reflective writing assignment. To explore statistically significant differences in the individual maximum scores between the course sections with and without reflective assignments, we inspected the univariate results of the MANOVA. The results revealed statistically significant differences for the maximum value of the knowledge component of each of the WCE attributes (Solidly Grounded: $F(1, 46) = 6.7, p = .013$; Technically Broad: $F(1, 46) = 11.4, p = .002$; and Effective in Team: $F(1, 46) = 5.3, p = .023$), while only one of the WCE attributes (Solidly Grounded: $F = 7.5, p = .02$) showed statistically significant differences for the maximum value of the interest component. This means that the reflective writing assignment proved most effective for the knowledge component across all WCE attributes. The fact that the overall MANOVA analysis did not reveal a statistically significant result may be attributable to the low numbers of participants in each of the sections. A larger sample is needed to confirm this.

Maximum value for:	Reflection	Mean	Std. Dev.	N
Solidly grounded knowledge	No	1.30	.66	20
	Yes	1.85	.77	27
Solidly grounded strategies	No	.50	.61	20
	Yes	.63	.69	27
Solidly grounded interest	No	.60	.94	20
	Yes	1.41	1.22	27
Tech broad knowledge	No	1.40	.50	20
	Yes	2.07	.78	27
Tech broad strategies	No	.60	.68	20
	Yes	.85	.72	27
Tech broad interest	No	.70	.98	20
	Yes	1.04	1.16	27
Effective in teams knowledge	No	1.60	.82	20
	Yes	2.11	.70	27
Effective in team strategies	No	.60	.75	20
	Yes	1.04	.76	27
Effective in team interest	No	1.40	.94	20
	Yes	1.56	1.15	27

Table 2: Knowledge, strategies, and interest evaluations

Conclusions and Implications

The pilot in the spring 2007 semester provided much insight into the kinds of prompts students need to encourage them to write in more depth about their learning experiences. It is important to keep in mind that students are evaluated on what they write about their learning, not on their learning in itself. As the results of this study show, when students are asked explicitly to reflect on their learning, their evidence of learning is evaluated as more advanced, especially on the

knowledge dimension. This does not necessarily mean that students in the section without a reflective writing assignment learned less; students just didn't write about it as much. Thus, it appears necessary to ensure that students are motivated to write about their learning. Therefore, the development of good prompts to ensure high levels of engagement and motivation is essential.

Motivating students to write about their learning is an issue in itself as well. We expect that responses from students who think seriously about their development related to the World Class Engineer attributes will contain information that places them relatively high on the scale, even if they do not write much. In other words, the length of the reflection is far less important than the content. Consider a scenario in which two students each provide a very limited response. If one student has thought deeply about the reflection questions while the other has not, the quality of their short responses should demonstrate the difference between them and the evaluation of their responses should identify these differences, irrespective of the length of the reflection.

An important issue to keep in mind is whether students develop an e-portfolio mainly to serve an educational or an assessment purpose. Rubrics must serve two purposes: to communicate high expectations to students and to evaluate contributions (evidence). E-portfolio development has been known for its educational value. On the assessment side, if one chooses to grade e-portfolios, it would be reasonable to grade the quality of students' reflections in combination with their evidence. While students with more challenging experiences (participating on a team that did not work well together, for example) have more room for growth, we argue that students with less challenging experiences (encountering a positive team experience) should still be able to explain what occurred to demonstrate insight in an aspect of their educational experience (in this example - teamwork).

It is also important to take into account that the expert levels as defined by Alexander⁵ are relative. The World Class Engineering attributes are meant to make students *aspire* to become World Class Engineers (experts). Most likely, students will graduate at the proficiency level at most, not the expert level. In other words, students should all realize that their undergraduate education *lays a foundation* for becoming a World Class Engineer. What we need to capture is their growth toward this proficiency. An e-portfolio is a great tool to communicate high expectations, but those should be different for students at different levels of their education. For example, we should communicate to first year students what we expect them to be able to do after the first year. The idea is to set realistic goals for each year for each of the WCE attributes to keep students motivated and engaged.

We are currently implementing the second round of e-portfolio piloting, which utilizes the prompts we are testing in one section of a first-year design course, one section of a junior level engineering entrepreneurship class, and in four sections of a sophomore level "Strength of Materials" course with a large enrollment. Our current trials are also aimed at streamlining the process so that the 'typical' engineering educator can consider using them in their classes in the future without having to invest much time.

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